Indian J. Phys. 76A (1), 13-14 (2002)

IJP A
an international journal

Elastic property of organized lipid assembly – an electrical study

D Ghosh, R Basu[1], S De[2] and P Nandy*

Department of Physics, Jadavpur University, Calcutta-700 032, India
[1]Department of Physics, Jogamaya Devi Collage, 92 S. P Mukherjee Road, Calcutta-700 026, India
[2]Department of Physics, Dinabandhu Mahavidyalaya, Bangaon, North 24 Parganas, West Bengal, India

E-mail : papiya@juphys ernet in

Abstract The Freedericksz transition is a well-studied phenomenon in thermotropic liquid crystals. Here, above a certain critical value of the applied electric field, the orientations of the directors of a sample of liquid crystal change abruptly resulting in a sharp transition in the capacitance of the sample.

Using lipid molecules that have been properly aligned on polyvinyl alchool coated glass electrodes, we have studied the effect of electric field on the capacitance of this system. In this case, a transient pattern similar to that of Freedericksz transition in liquid crystals has been observed. From the experimental data, the value of the splay elastic constant k_{11} of this system has been calculated.

Keywords : Lipids, electrical study, Freedericksz transition

PACS Nos. 87 14 Cc, 62 20 Dc, 87 15 -v

1. Introduction

Liquid bilayer, being the key element of biological membranes, is used as a model to study various membrane based physicochemical processes [1-4]. The conformational properties of the lipid matrix are closely related to the thermodynamic and mechanical properties of the membrane, such as its bending rigidity and stretching elasticity. Large scale computer simulations can provide detailed structural and dynamical information on self-assembling lipid aggregates. However, the calculation of elastic properties is difficult as it requires systematic simulation subject to varying boundary conditions.

The configurational similarities between thermotropic liquid crystals and organized lipid assembly prompted us to adopt some experimental methods which have been used earlier to measure the elastic constants of liquid crystals [5,6]. In our experiment, we have measured the capacitance of an organised assembly of phospholipid with varying voltage and from the data, the value of the splay elastic constant k_{11} has been calculated. The experimentally obtained value agrees quite well with the results obtained by other methods[7].

* Corresponding Author

2. Methods

The lipid dipalmitoyl phosphatidylcholine (lecithin), purchased from Sigma Chemical Company and chlorofom from SD Chemicals were used without further purification. Polyvinyl alcohol (PVA) from BDH Chemicals was a gift from the laboratory of Professor S K Roy (Department of Physics, Jadavpur University, Kolkata, India) SnO_2 coated glass electrodes were gift from the laboratory of Professor E Sackmann (Technical University, Munich, Germany). All measurements were taken in a HP 4274A multi-frequency LCR meter at 25°C.

A solution of PVA in water was prepared having final concentration 1%. The PVA solution so prepared was spread

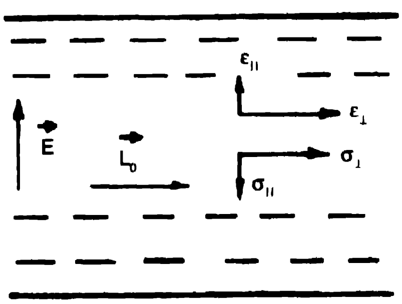

Figure 1. The usual geometry of a sandwich cell.

on a pair of SnO_2 coated glass plates and baked in an oven at about 120°C for 30 minutes, so that a thin film of PVA was formed on the glass plates. Antiparallel striations were made on this PVA film by repeated rubbing with a filter paper. A dry lecithin film was formed by repeated pipetting out lecithin solution in chloroform in minute quantities on the PVA coated glass plates and subsequently drying it. Finally, the two glass plates were sealed using a suitable adhesive and hence a dry lecithin film between two glass electrodes was obtained. Electric connections with the glass electrodes were made by means of conducting circuit epoxy. Figure 1 shows the usual geometry for a sandwich cell.

3. Results and discussion

The value of capacitance (C_0) of the experimental PVA coated cell is 113 pF In Figure 2, the value of capacitance of the PVA coated cell with lipid spread over it, has been plotted as a function of applied voltage at a constant frequency ~ 1KHz. The curve shows a sharp transition from an average value of capacitance C_2 = 5.00 pF at a low field value to an average value of capacitance C_1 = 260 pF at a high field value. The sharp transition takes place at a voltage, V_{th} ~ 1.45V, indicating a change in the orientation of the molecules at that voltage. When the electric field is switched off, the initial low value of the capacitance is regained

Figure 2. Variation of the capacitance of the dry lipid film with applied voltage when the frequency is kept fixed at 1 KHz

In Figure 3, the value of capacitance at temperature 25°C has been plotted as a function of frequency at the constant applied voltage (V = 1 Volt). The curve shows a rapid decrease in the value of capacitance with increase in frequency. The splay elastic constant (k_{11}) of a sample of liquid crystal confined in a cell, is related to the threshold voltage V_{th} and the dielectric constants in the direction parallel (ε_1) and perpendicular (ε_2) to the direction of the electric field by the following equation[5]

$$k_{11} = (V_{th} / \pi)^2 \varepsilon_0(\varepsilon_1 - \varepsilon_2),$$

where $\varepsilon_1 - \varepsilon_2 = (C_1 - C_2)/C_0$, $\varepsilon_0 = 8.85 \times 10^{-12}$ Farad/metre.

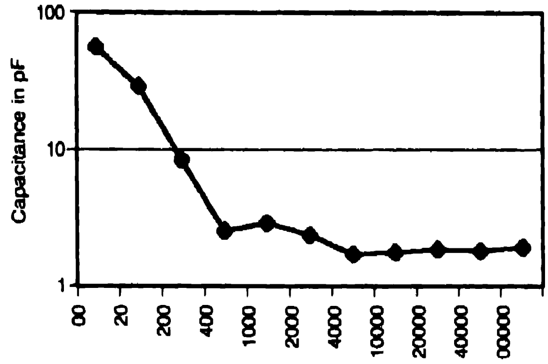

Figure 3. Variation of the capacitance of the dry lipid film with the frequency of the applied electric field when the voltage is kept fixed at 1 Volt

The value of the dielectric constant [4] for the lipids lies between 2 and 3. As this is the ratio of two capacitances, the actual value of the sample thickness (which is of the order of several microns) does not explicitly appear in the calculation.

Using the above formula and from our experimental results, the value of k_{11} is obtained to be ~ 8.514×10^{-7} dyne at 25°C.

This value agrees quite well with the calculated value of k_{11} ~ 10^{-6} dynes for lipid bilayer membranes [7,8].

Acknowledgment

Financial assistance from the Council of Scientific & Industrial Research, Govt of India is gratefully acknowledged. We also thank Dr. S. K. Roy, Dr. S. Banerjee, Mr. S. Datta, Mr. S. Saha and Ms S. Dasgupta for their help.

References

[1] R Datta, P Nandy and B B Bhowmik *Mol Cryst Liq Cryst* **150** 325 (1987)

[2] D Houbre, P Schindler, E Trifilief, B Luu and G Duportail *Biochim. et Biophys Acta* **1029** 136 (1990)

[3] D Bhattacharya, R Basu, A Ghosh, A Nandy, A Manna and P Nandy *Biophys. J* **64** 550 (1993)

[4] R Basu, S De, S Nayar, S Das, A K Ghosh and P Nandy *Phys Rev* **E52** 4179 (1995)

[5] P Chattopadhyay and S K Roy *Mol Cryst Liq Cryst.* **257** 89 (1994)

[6] N V Madhusudana and R Pratibha *Mol. Cryst Liq Cryst.* **89** 249 (1982)

[7] W Helfrich *Z. Naturforsch* **28c** 693 (1973)

[8] O Y Zhong-Can, L Ji-Xing and X Yu-Zhang in *Geometrical Methods in the Elastic Theory of Membranes in Liquid Crystal Phases.* (Singapore . World Scientific) Chap 2 (1999)